



**PROGRAM** : BACCALAUREUS TECHNOLOGIAE (BTECH)  
(ENGINEERING METALLURGY)

**SUBJECT** : **METALLURGICAL  
THERMODYNAMICS 3**

**CODE** : **THM32-1**

**DATE** : NOVEMBER EXAMINATION  
13 NOVEMBER 2019

**DURATION** : 08:30 - 11:30 (3 HOURS)

**WEIGHT** : 40:60

**TOTAL MARKS** : 120

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**ASSESSOR** : **Mr MB MOLALA**

**MODERATOR** : **Mr ELVIS GONYA**

**NUMBER OF PAGES** : 4

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**INSTRUCTIONS**

- First read carefully through all questions; only then
- Answer all questions in any sequence
- Please start answering each question on a new page
- One Calculator per student

### Question 1

1.1 Methane cannot be synthesized by direct combustion of carbon and hydrogen.

Calculate the standard enthalpy of formation of methane from enthalpies of combustion of methane, carbon and hydrogen:

- $\text{CH}_4(\text{g}) + \text{O}_2(\text{g}) = \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$   $\Delta H^\circ_{\text{c}} = -890 \text{ kJ/mol}$
- $\text{C}(\text{s}) + \text{O}_2(\text{g}) = \text{CO}_2$   $\Delta H^\circ_{\text{c}} = -393 \text{ kJ/mol}$
- $\text{H}_2 + 0.5\text{O}_2 = \text{H}_2\text{O}(\text{l})$   $\Delta H^\circ_{\text{c}} = -278 \text{ kJ/mol}$

(10)

1.2 Does the enthalpy change of formation of water vapour increase or decrease with rise in temperature?

<u>Given</u>	<u>Equation &amp; Data</u>
<ul style="list-style-type: none"><li>• <math>C_p: \text{H}_2 = 28.9 \text{ J/K/mol}</math></li><li>• <math>C_p: \text{H}_2\text{O} = 33.5 \text{ J/K/mol}</math></li><li>• <math>C_p: \text{O}_2 = 29.4 \text{ J/K/mol}</math></li></ul>	<ul style="list-style-type: none"><li>• <math>\text{H}_2(\text{g}) + 0.5\text{O}_2 = \text{H}_2\text{O}(\text{g})</math></li><li>• Temperature @ 298K</li><li>• <math>\Delta H = \text{Negative } (-)</math></li></ul>

(5)

1.3 Indicate using a graphical representation, enthalpy variation with temperature (5)

[20]

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### Question 2

2.1 What is the amount of heat (energy) required to melt 1kg of silver?

Given:

- Mass of silver (m) = 1kg
- Mol mass of silver (M) = 108g/mol
- Melting point ( $T_m$ ) = 960°C
- $C_p = 24.4 + 2.5 \times 10^{-3} \text{ J/(mol.k)}$
- $H_{\text{fus}} = 11\,304 \text{ J/mol}$

(10)

- 2.2 Indicate using a graphical representation, heat capacity variation with temperature (5)

**[15]**

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**Question 3**

- 3.1 List and discuss four (4) processes involving entropy change (10)
- 3.2 Show equations which indicate entropy changes during **change of state, change of temperature, and chemical reaction** (10)

**[20]**

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**Question 4**

- 4.1 Calculate the entropy of liquid Iron at it's melting point, 1808K

**Given:**

$$L_f = 15.4 \text{ kJ/mol}$$

$$S^\circ_{298} = 27.2 \text{ J/k.mol}$$

$$C_p = 25.2 \text{ J/k.mol} \quad (5)$$

- 4.2 Discuss how a chemical reaction will behave spontaneously when  $\Delta S_{\text{total}}$  is 0, negative (-) & positive (+) (5)

- 4.3 Calculate the standard entropy of solid copper at 1073°C from the following data

Given:

$$S^\circ_{298} = 33.4 \text{ J/k.mol}$$

$$C_p = 22.63 + 6.27 \times 10^{-3} T \text{ J/k.mol} \quad (5)$$

**[15]**

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### **Question 5**

- 5.1 Prove mathematically how  $\Delta G$  varies with temperature (10)
- 5.2 Differentiate between an acid slag and a basic slag (3)
- 5.3 State the basic functions of slag & their fundamental properties (12)
- 5.4 Calculate the electrode potential of Zn ( $E_{\text{Zn}}$ ) at 298K when the  $a_{\text{Zn}^{2+}} = 0.01$  if  $E_{\text{Zn}}^{\circ} = -0.763\text{V}$  at this temperature (5)

**[30]**

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### **Question 6**

- 6.1 The reversible e.m.f. between pure magnesium and magnesium-zinc alloy containing 63.5 atom% magnesium in a fused KCl-LiCl-MgCl<sub>2</sub> electrolyte may be represented by  $E = 16.08 \times 10^{-3} + 1.02 \times 10^{-5}T$ , where E and T are in V and K respectively. Calculate the activity coefficient and excess partial molar free energy of mixing of magnesium in the above alloy at 727°C (1000 K). (20)

**[20]**

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**TOTAL MARKS:** **[120]**

## FORMULAE-LIST

1.  $\frac{dP}{dT} = \frac{\Delta H}{T\Delta V}$
2.  $\ln \frac{P_2}{P_1} = \frac{\Delta H}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$
3.  $\Delta G^\circ = -RT \ln k$
4.  $\Delta G_A = RT \ln \gamma_A + RT \ln \left( \frac{M_B}{100M_A} \right)$
5.  $\Delta G^M = RT (X_A \ln a_A + X_B \ln a_B)$
6.  $\Delta S^M = -R (X_A \ln X_A + X_B \ln X_B)$
7.  $\Delta H^M = RT (X_A \ln \gamma_A + X_B \ln \gamma_B)$
8.  $G_A^{XS} = RT \ln \gamma_A$
9.  $N = \frac{L}{T} \times \frac{273}{0.022414}$
10.  $m = \frac{M}{L}$
11.  $\square c = \sqrt{\frac{8RT}{\pi M}}$
12.  $d = \sqrt{\frac{cm}{2\sqrt{2}\pi\mu}}$
13.  $U = \frac{m_A m_B}{m_A + m_B}$
14.  $Z_{AB} = N_A N_B d_{AB}^2 \sqrt{8\pi k T u^{-1}}$
15.  $\Delta G^{XS} = X_A \Delta G_A^{XS} + X_B \Delta G_B^{XS}$
16.  $V = Z A e^{\frac{-E}{RT}}$
17.  $\log f_A = \text{wt \% A } e_A^A + \text{wt \% B } e_A^B + \text{wt \% C } e_A^C$  (e = interaction-parameter)
18.  $S_A = k \sqrt{P_A}$
19.  $\ln f_B = X_B e_B^B + X_C e_B^C + X_D e_B^D$
20.  $\frac{-d[C]}{dT} = D \frac{[O]_{sat} - [O]}{|\Delta t|} \times \frac{12}{16}$
21.  $\Delta T_A = \frac{X_A R T_{OB}^2}{H_{OB}}$
22.  $\Delta G = -ZFE$
23.  $\Delta S = ZF \left[ \frac{\partial E}{\partial T} \right]_P = S^M (\text{molar})$
24.  $\Delta H_A = -ZF \left[ E - T \left( \frac{\partial E}{\partial T} \right) \right] = H^M_A$  (molar)
25.  $\Delta G_A = RT \ln a_A + \Delta G^\circ$
26.  $\Delta G = \Delta H - T \Delta S$
27.  $t_x = \frac{1}{k} \ln \left( \frac{c_o}{c_o - x} \right)$
28.  $k = A e^{\left( \frac{-E}{RT} \right)}$
29.  $t_{0.5} = \frac{1}{kC}$  or  $\frac{\ln 2}{k}$
30.  $k = \frac{1}{t} \times \frac{x}{c_o(c_o - x)}$